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(19)

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(54) BURNER WITH FLAME PATTERN CONTROL

(71) We, AIRCO, INC, a body corporate organised and existing under the laws of the State of New York, United States of America, having an office at 150 East 42nd Street, New York, New York 10017, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention concerns burners of the type generally known as "rocket burners", in which oxygen and fuel respectively are fed as required to the burner for combustion and projection of heating flames. Control of the physical size and shape, i.e. pattern or configuration, of the burner flames is essential for many applications, such as for example where short, bushy or spreading flames best serve the heating purpose; in other applications, a long slender, needle-type flame may be indicated.

Although flame pattern control for oxygen-type fuel burners has heretofore been proposed and practiced, it has not been satisfactorily achieved insofar as known, in modern acceptable burner equipment. For example, a prior art device known as the "shell-type" burner utilizes the needle valve principle for changing the flame pattern. In this burner the oxygen is fed through a cylindrical housing or shell and mixed with fuel gas from a central feeder that is axially adjustable in the shell for defining an annular nozzle type opening, constituting an adjustable burner passage. The burner also includes a so-called "bluff body" flame stabilizer and spreader that is in direct contact with the oxygen-fuel flame at the point of mixing. As indicated above, control of the flame pattern of the "shell burner" is accomplished by axial movement of the central fuel feeder for varying in the manner of needle valve control, the annular passage for directing an oxygen-fuel mixture into the combustion region at the bluff body.

Serious difficulties and disadvantages were encountered in the operation of the "shell burner." Premature ignition of the highly combustible oxygen-fuel mixtures within the burner itself created a dangerous explosion hazard; also excessive maintenance was involved due to the difficulty of properly cooling the burner parts in direct contact with the hot oxygen-fuel flames. For these reasons general use of the "shell burner" has greatly declined.

A more acceptable oxygen-fuel burner now in common use is known as the "rocket burner", a typical example being shown by U.S. Patent No. 3,135,626. Briefly, the "rocket burner" comprises a cylindrical combustion chamber open at the discharge end and having a multi-port burner plate forming the opposite end of the chamber. Fuel gas and oxygen are separately fed in closely grouped parallel streams through respective ports in the burner plate for mixing and burning in the combustion chamber. Initially, this is accompanied by establishment of low velocity anchoring flames as gases along the peripheries of adjacent fuel and oxygen streams mingle after passing through the burner plate ports.

In this prior art rocket burner, a limited degree of flame pattern control can of course, be achieved by valve regulation of the amounts, pressures and ratios of the oxygen and fuel fed to the burner; also by locating the burner plate at selected distances from the burner exhaust, an elongated "stiff" flame or a comparatively short, fat flame can be produced. However, regulation of the oxygen and fuel burner input does not provide for flexibility in varying the flame pattern for a given BTU burner output. Location of the burner plate at different distances from the burner exhaust also does not achieve the desired control of flame pattern as the closely grouped parallel gas streams from the conventional burner plate ordinarily start mixing and burning well within the com-

bustion chamber near the burner plate and tend to diverge downstream. Where the burner plate is comparatively close to the exhaust of the combustion chamber, bushy type flames naturally result, however, a widespreading umbrella-shaped flame is not possible with this conventional type of rocket burner.

The invention therefore is concerned with providing an improved burner having flexible flame pattern control over a wide range for a given BTU burner output, and also with providing a method for controlling the pattern of flame discharged from the chamber of a burner.

Accordingly this invention now provides an oxygen-fuel burner having a cylindrical combustion chamber with a closed feed end and an open end for flame discharge, and comprising:—

a plurality of fluent fuel inlets at the fuel end, each arranged to direct a stream of fluent fuel generally parallel to the longitudinal axis of the chamber towards the open end; and

a plurality of oxygen inlets at the feed end and each arranged to direct a stream of oxygen towards the open end at an angle to the longitudinal axis of the chamber such that each oxygen stream intersects a corresponding said fuel stream;

the length of the chamber between its open and feed ends being adjustable to vary the confining effect of the chamber on the flame discharged from its open end.

In the preferred form of the burner of the invention, each oxygen inlet is radially spaced from the axis and arranged to direct its stream of oxygen along a path not intersecting, but initially converging on the axis. Preferably a first group of the fuel inlets are arranged to direct their fuel streams to intersect the corresponding oxygen streams in a primary combustion region where the latter are still converging toward the axis, and a second group comprising the remaining fuel inlets are arranged to direct their fuel streams along the periphery of the chamber to define a secondary fuel envelope which is intersected in a secondary combustion region by said oxygen streams when diverging from the axis, the said fuel inlets being so proportioned that most of the fuel is directed to the secondary rather than to the primary combustion region.

Thus, in this preferred form the location of the region of initial mixing, or the primary combustion region, is determined by the interaction of the fuel streams from the first group of fuel inlets with the corresponding streams of oxygen, the rectlinear paths of which first converge upon and then diverge from the axis owing to their non-intersecting relationship therewith. The oxygen inlets are preferably arranged at identical angles to the axis, so that the points of nearest approach of the oxygen streams to the axis lie in a plane transverse to the axis — the "plane of nearest approach." It is preferred that the region of primary combustion should lie in and around this plane.

Beyond the plane of closest approach the paths of the oxygen streams diverge from the axis. The position of the plane of closest approach relative to the open end of the chamber thus governs the nature of the flame produced by the burner, because where the paths of the divergent oxygen streams pass out of the open end without impinging on the walls of the chamber a bushy, wide-spreading flame is formed, whereas where the said divergent paths impinge upon the walls of the chamber an elongated, sharp and jet-like high velocity flame is formed. In accordance with the invention, variation of the flame pattern within these limits is achieved by making the length of the chamber — i.e. the distance between its feed and open ends — adjustable; variation in the length of the chamber alters the relative positions of the plane of closest approach and the open end, and thus the flame pattern. By use of this mode of flame pattern control one can achieve wide variation in flame pattern for a given BTU burner output.

According to a preferred embodiment of the invention, which is particularly described below, the burner comprises a housing having a cylindrical part with an open end, inside which cylindrical part a burner plate is mounted for longitudinal axial movement, all the fuel and oxygen inlets being formed in the burner plate, and the combustion chamber being defined by the cylindrical part, the open end, and the burner plate. Thus the desired variation in the length of the chamber is achieved by longitudinal movement of the burner plate within the cylindrical part of the housing.

This invention further provides a method of controlling the pattern of flame discharged from the chamber of an oxygen-fuel burner having a cylindrical combustion chamber of adjustable length with a closed feed end and an open flame discharge end, comprising:—

(1) feeding a plurality of fluent fuel streams from the feed end and generally parallel to the longitudinal axis of the chamber towards its open end;

(2) feeding a plurality of oxygen streams from the feed end toward the open end at an angle to the longitudinal axis of the chamber such that each oxygen stream intersects a corresponding said stream of fuel from the feed end; and

(3) adjusting the length of the chamber between its feed and open ends so as to vary

the confining effect of the chamber on the pattern of the flame discharged therefrom.

The preferred features and explanation of this method appear from the above description of the burner according to the invention.

Preferred embodiments of the burner and method of the invention will now be particularly described with reference to the accompanying drawings, in which:—

Fig. 1 is a perspective view, partly in section, of an oxygen-fuel burner according to the invention;

Fig. 2 is a plan view of the multi-port burner element of the burner shown in Fig. 1;

Fig. 3 is a sectional view taken along the line 3—3 of Fig. 2;

Fig. 4 is a diagrammatic view of the burner element and combustion chamber of the burner shown in Fig. 1 indicating convergence of two oxygen streams toward the chamber axis;

Fig. 5 is a diagrammatic plan view indicating the relation of the oxygen streams to the chamber axis at the plane of closest approach along line 5—5 of Fig. 4; and

Figs. 6, 7 and 8 are diagrammatic views illustrating respectively, different positions of the burner element with respect to the combustion chamber exhaust for achieving different patterns of the exhaust flames in the burner of Fig. 1.

The oxygen-fuel burner 10 shown by way of example in Fig. 1, comprises a cylindrical housing 12 within which a burner element 14 defines one end of a cylindrical combustion chamber 16. The open end of the housing at 18 defines the opposite or discharge end of the chamber from which heating flames are projected for heat working, space heating and the like. As the combustion chamber is subject to the high temperatures encountered in the operation of oxygen-fuel burners, the housing 12 includes a water-cooled jacket 20 that extends throughout the length of the combustion chamber and most of the housing for effective heat dissipation.

The burner element 14, herein for convenience termed "burner plate", constitutes in effect a flow divider for separately feeding a plurality of oxygen and fuel streams respectively into the combustion chamber. In the present example, the burner plate is formed as an apertured disc-like cylinder that is coaxially mounted within the combustion chamber and serves as a partition between the combustion chamber and an elongated plenum chamber 22 for the fuel. The plenum chamber extends from the burner plate to the opposite end of the housing where it is connected to a fuel supply conduit at 23, that conveniently may be utility natural gas.

Certain of the burner plate apertures or ports are located around the centre of the plate, as at 24 for example, and extend through the burner plate for directly communicating with the fuel plenum chamber 22. A plurality of other ports 26 for supplying oxygen to the combustion chamber are arranged in a circle, preferably concentric with the longitudinal axis of the combustion chamber (and burner plate), around the smaller centrally grouped fuel ports 24. Additional fuel ports 28 in the burner plate, also communicating with the fuel chamber 22, are disposed in a circle around the outer peripheral area of the oxygen ports 26. The central fuel ports 24, shown as 6 in number, and the outer fuel ports 28, also 6 in number, extend normally through the burner plate so that the axes of the respective ports extend generally parallel to the longitudinal axis of the combustion chamber. The oxygen ports 26, however, are angularly disposed with respect to the chamber axis, the projected longitudinal axes of which ports 26 converge toward the open end of the chamber in off-set, non-parallel, non-intersecting relation to the chamber axis so as to be in non-intersecting relation therewith. That is, the longitudinal axes of the oxygen parts are inclined toward and skewed somewhat with respect to the chamber axis as indicated in Fig. 2 for establishing the geometric relation described above.

The oxygen ports 26 are connected to an oxygen supply through a manifold arrangement that comprises a plurality of tubes 30 interconnecting the corresponding oxygen ports and a header 32. The header in turn, is fed by a conduit 34 that extends longitudinally through the chamber 22 and the housing to the exterior thereof for connection as indicated with a source of pressurized oxygen.

It will be apparent that in the apparatus so far described, separate supplies of oxygen and fuel are fed to the corresponding ports in the burner plate, the oxygen from the conduit 34 and manifold to the ports 26, and the fuel from the supply line at 23 and plenum chamber 22 directly to the burner plate ports 24 and 28. Accordingly, the burner plate ports direct as indicated above, separate streams of oxygen and fuel respectively into the combustion chamber 16 for mixture beyond the burner plate and subsequent burning as more fully described below.

The combustion chamber walls as mentioned above are protected from overheating by a water-cooled jacket 20 constituting part of the housing 12 and consisting of coaxial tubular walls 36, 38 and 40 that are spaced in the usual manner for defining annular, reverse-flow cooling paths.

As shown, the cooling path extends from the cooling water inlet 42 through the annular passage 44 defined by walls 38 and 40 to the burner exhaust end, where the flow reverses into the annular passage 46 formed between the walls 36 and 38, and thence to the cooling water outlet 48.

The materials of construction for the present burner may conform in general to those used in previous known burners of the rocket type; i.e. the burner plate may be made of copper or tellurium copper, and the cylinders of the housing, cooling jacket and combustion chamber made of brass or stainless steel, according to required thermal conductivity, flame-corrosion resistance, etc.

In practicing the invention, the position of the burner plate 14 is adjustable along the longitudinal axis of the combustion chamber with respect to the chamber exhaust; i.e. the burner plate can be moved toward or away from the chamber exhaust for in effect changing the length of the combustion chamber, and thereby the pattern of the exhaust flames. To this end, the burner plate 14, manifold 30—32, and conduit 34 are integrated as a structural unit for relative movement with respect to the housing 12. The burner plate has a sliding fit with the inner cylinder wall 40 constituting the combustion chamber wall, and the conduit 34 is guided for longitudinal movement by a sealing bushing 50 through the end wall 52 of the housing. Relative movement between the burner plate assembly and the housing can be achieved in any suitable manner; for example, a gear rack 54 that is connected to the conduit, is engaged by a coacting pinion 56 that in turn is manually operated at 58 for moving the conduit (and the burner plate) longitudinally in either direction.

Reference is now made to Figs. 2 and 3 for illustrating the specific arrangement of the burner plate ports for directing interacting streams of oxygen and fuel respectively into the combustion chamber. Taking for example the oxygen port 26*a*, it will be noted that the longitudinal axis 26′ thereof is skewed with respect to the center of the burner plate, i.e. the longitudinal axis of the combustion chamber, so that intersection of the port axis 26′ with the chamber axis 16′ is not possible. It will also be noted that the oxygen port axis 26′ intersects with the longitudinal axis of one of the centrally located small fuel ports 24*b*, hereinafter referred to as "primary fuel" ports, for ensuring mixing of these two streams. Moving clockwise, it will also be seen that the other oxygen ports 26*b*, 26*c*, etc., are similarly skewed with respect to the chamber axis and have their respective longitudinal axes oriented for intersecting with corresponding axes of primary fuel ports 24*c*, 24*d*, etc.

Fig. 3 illustrates the angular direction of the oxygen ports 26*a* and 26*d* for directing oxygen streams in converging direction toward the chamber axis 16′, but in offset, non-intersecting relation threto as best illustrated in Fig. 2. The oxygen streams from the 6 ports shown in Fig. 2 therefore tend to form a clock-wise vortex (as seen in Fig. 2) around the chamber axis at a region remote from the burner plate.

Figs. 4 and 5 which diagrammatically supplement Figs. 2 and 3, indicate the relationship between the projected longitudinal axes of the oxygen ports and the extension of the chamber axis 16′. In the partly sectional view of the combustion chamber and burner plate shown by Fig. 4, the burner plate is in a similar position to that shown in Fig. 3. The oxygen streams from the ports 26*a* and 26*d* are represented for convenience in illustration, as straight high velocity jets or stream cores 0—1 and 0—4, disregarding for the moment any modifying effects of the fuel streams (not shown) from the primary fuel ports 24*a* and 24*d*, etc. Although the axes 26′ of the two skewed streams appear in Fig. 4 to intersect each other and the chamber axis 16′ at some point beyond the section line 5—5, their closest approach to the axis actually occurs at the section line. Accordingly, the transverse plane or region determined by the section line 5—5 is referred to herein as the "plane of closest approach." Fig. 5 taken along this section line shows the skewing angle α of the oxygen streams 0—1 and 0—4 as about 60° in clockwise direction from the initial positions of Fig. 3 as represented by the horizontal or transverse burner plate axis 14′. The other oxygen streams 0—2 and 0—3, etc., re assumed to be skewed uniformly in the same direction as best shown in Fig. 2.

Between the plane of closest approach and the chamber exhaust, the oxygen streams begin to diverge toward the combustion chamber wall. Fig. 6 illustrates schematically this divergence for a given advanced position of the burner plate wherein the combustion chamber is comparatively short. In this example, divergence of the oxygen port axes extends beyond the chamber exhaust.

Returning briefly to Fig. 2, it will be seen that the additional or secondary fuel ports 28 along the peripheral area of the burner plate are designed to supply the main volume of comparatively low velocity fuel to the combustion chamber. As the axes of these ports, as in the case of the central or primary fuel ports 24*a*, 24*b*, etc., extend generally parallel to the chamber axis, the secondary fuel streams form in effect a low velocity fuel envelope at the chamber

periphery surrounding the oxygen and the primary fuel streams.

In Fig. 6, the sectional view is intended to indicate the interaction of the oxygen and fuel streams in and beyond the combustion chamber, rather than the precise scalar relationship of the axes in Figs. 2, 3 and 4. It was found in developing the present invention that a wide spreading, bushy or "umbrella" type flame for the burner as represented by Fig. 6 is best achieved by using the momentum of high velocity oxygen streams directed in both converging and skewed directions with respect to the combustion chamber axis for locating the plane of closest approach sufficiently near the chamber exhaust that the divergence of the high velocity stream is not confined by the chamber walls. By avoiding convergence carried to actual intersection of the oxygen stream axes, as at some common point on the chamber axis, serious problems involving limitation of flame length,, combustion chamber cooling, etc., are avoided and the advantages of free fuel and flame divergence beyond the plane of closest approach for producing the desired umbrella-type flame are retained.

Referring more specifically to the burner operation, the primary combustion mechanism in the illustrated burner, while somewhat similar to that described in U.S. Patent No. 3135626 (mentioned above), wherein holding flames for stabilizing the main combustion chamber flames are established in a low velocity region near the discharge side of the burner plate, actually differs materially therefrom by establishing primary combustion for the stabilizing flames in a chamber-centered region a material distance from the burner plate. This is achieved by feeding the primary supply of fuel from the burner ports 24*a*, 24*b*, etc., directly into the converging oxygen streams entering the region of closest approach, Figs. 2 and 6. As the oxygen and primary fuel streams gradually converge, the respective streams mix and provide as schematically indicated at 25 low velocity holding flames.

The size of the burner ports 24*a*, 24*b*, etc., is preferably such that the primary supply of fuel admitted by them is less, preferably substantially less, than the secondary supply admitted by the outer ports 28.

This introduction of a small amount of fuel into the oxygen streams at the plane of closest approach, produces a transversely extending region for the primary and stabilizing combustion. This region is in a fuel mixture zone of relatively low velocity, extending to the enveloping fuel streams Fs. Secondary combustion is therefore effectively stabilized by direct communication with the primary combustion zone. The size and spread of this zone, referring to Fig. 5, is readily controlled in the design, according to the convergence and skewing angles of the oxygen port axes. As the diverging oxygen streams from the region of closest approach continue to diverge toward the chamber exhaust and mix with the enveloping main supply of secondary fuel from the ports 28, combustion of the mixed oxygen and fuel is ensured by the primary combustion or holding flames at the region of closest approach as indicated in Fig. 6.

The secondary combustion region, i.e. where combustion of the spreading mixed oxygen and fuel is completed, extends beyond the chamber exhaust as indicated and is determined generally by the velocity and divergence of the oxygen streams with respect to the chamber exhaust and the amount of fuel from the ports 28. It will be seen from Fig. 6 that the main or secondary fuel supply envelope from the ports 28 is traversed by and mixed with the stronger high velocity diverging oxygen streams 0—1 and 0—4, etc., with consequent spreading or mushrooming of the burning mixture beyond the chamber exhaust. Accordingly, a secondary combustion or flame region having the desired wide-spreading umbrella type pattern is established.

The degree of flame spread for a given burner plate adjustment can of course be further varied by empirical adjustment of the supply pressures for the oxygen and fuel streams. Variation of the oxygen-fuel ratio affects flame spread to the extent that a ratio giving an optimum fuel supply for producing combustible mixtures for the secondary combustion region, results in the largest secondary combustion region. Although the term "oxygen" as used herein generally refers to the preferred use of commercially pure oxygen, it is also intended to include oxygen-enriched gases in applications where the higher combustion temperatures obtainable by pure oxygen are not required.

Where the burner plate and plane of closest approach are located as illustrated in Fig. 7, so that the projected diverging axes 26' of the oxygen stream cores intersect the combustion chamber wall, as distinguished from Fig. 6 wherein divergence of the axes beyond the plane of closest approach is not restricted by the chamber wall, mixing and initial secondary combustion of the enveloping fuel streams Fs and the oxygen streams 0—1 and 0—4, etc., are confined to a greater extent within the now elongated combustion chamber 16. That is, as the chamber wall is now effective to deflect the oxygen streams generally along and into the enveloping fuel streams, mixing of the oxygen and secondary fuel tends to take place mainly within the combustion

chamber. The momentum of the oxygen streams, combined with the chamber pressure incident to secondary combustion, produces a stiff, sharp and elongated flame at the combustion chamber exhaust. It is believed that this effect is due in part to the energy of the deflected oxygen cores, that tend to reconverge, somewhat as a tapering cone, on the chamber axis. Secondary fuel is during this process mixed with the oxygen and carried along toward the central axis of the chamber, where secondary combustion continues as the mixed fuel and oxygen and combustion flames are discharged at high velocity from the burner exhaust to form a long, needle-type flame.

Fig. 8 illustrates an intermediate adjustment of the burner plate for obtaining a flame pattern that represents a moderately bushy flame, materially longer than the umbrella type flame of Fig. 6. In this flame pattern adjustment of the projected longitudinal axes 26 of the oxygen stream cores barely clear the chamber exhaust so that part of the oxygen stream is deflected inwardly by the chamber wall. Accordingly, but part of the oxygen stream energy is available to spread the mixed oxygen and fuel and flame in divergent directions at the exhaust so that a modified bushy flame of moderate length is produced. It will be apparent from the descriptions of Figs. 6—8, that a wide range of graduated flame pattern control can be achieved by corresponding adjustment of the burner plate (and plane of closest approach) with respect to the chamber exhaust.

Summarizing briefly, it will be seen that the illustrated embodiment of the invention avoids certain prior art difficulties by the use of aerodynamic flame-holding for establishing an oxygen-fuel mixing region remote from any part of the burner plate, thereby isolating the moveable burner plate from any contact with flame or combustible oxygen-fuel mixtures.

In practice, the illustrated burner embodying the invention is flexible in scope of operation; all gaseous, or atomizable or vapourizable fuels can be burned at high efficiency without major design changes, and optimum conditions for a given fuel can be obtained by adjustment of design parameters. The term "fluent fuel" as used in the Specification therefore includes, as well as truly gaseous fuels such as natural gas, vapourized or atomized liquid fuels. Basic variable factors of the burner include the burner BTU output that is determined by the amounts of oxygen and fuel supplied, the angle of exhaust flame divergence determined by the position of the burner plate (and the diverging and skewing angles of the oxygen stream cores), and the "turn-down ratio". The latter is defined in terms of the full range of burner operation for a stable flame situation. This can be quantitatively expressed as a ratio

$$\text{"}\frac{\text{BTU/hr, (max.)}}{\text{BTU/hr. (min.)}}\text{"}$$

Conventional commercial burners have in general a narrow range within which stable flame operation can be obtained, whereas burners embodying the present invention may have, for example, a turn-down ratio of about 1,000:1, that is determined by the burner dimensions, principally the diameters of the respective oxygen and fuel ports, and the angular relation of the port axes to the chamber axis.

Practical advantages of the invention also include improved flame stability by reason of the low velocity, centered primary combustion region, improved turn-down ratio, simplicity of design wherein a flame stabilizing bluff body or the like, in the flame is not needed, and greatly improved safety with practical elimination of preignition and explosion hazard.

WHAT WE CLAIM IS:—

1. An oxygen-fuel burner having a cylindrical combustion chamber with a closed feed end and an open end for flame discharge, and comprising:—

a plurality of fluent fuel inlets at the feed end, each arranged to direct a stream of fluent fuel generally parallel to the longitudinal axis of the chamber towards the open end; and

a plurality of oxygen inlets at the feed end each arranged to direct a stream of oxygen towards the open end at an angle to the longitudinal axis of the chamber such that each oxygen stream intersects a corresponding said fuel stream, the length of the chamber between its open and feed ends being adjustable to vary the confining effect of the chamber on the flame discharged from its open end.

2. The burner of claim 1 in which each oxygen inlet is radially spaced from the axis and arranged to direct its stream of oxygen along a path not intersecting, but initially converging on, the axis.

3. The burner of claim 2 in which a first group of the fuel inlets are arranged to direct their fuel streams to intersect the corresponding oxygen streams in a primary combustion region where the latter are still converging toward the axis, and a second group comprising the remaining fuel inlets are arranged to direct their fuel streams along the periphery of the chamber to define a secondary fuel envelope which is intersected in a secondary combustion region by said oxygen streams when diverging from the axis, the said fuel inlets being so proportioned that most of the fuel

is directed to the secondary rather than to the primary combustion region.

4. The burner of claim 1, 2 or 3 comprising a housing having a cylindrical part with an open end, inside which cylindrical part a burner plate is mounted for longitudinal axial movement, all the oxygen and fuel inlets being formed in the burner plate and the combustion chamber being defined by the cylindrical part, the open end and the burner plate.

5. The burner of claim 4 as dependent on claim 3 in which the first group of fuel inlets are arranged around the centre of the burner plate, the oxygen inlets are arranged around the first group of fuel inlets, and the second group of fuel inlets are arranged adjacent the circumference of the burner plate around the oxygen inlets.

6. The burner of claim 4 in which the projected longitudinal axes of the oxygen inlets at their points of closest approach to the axis of the chamber define a plane transverse to the axis.

7. The burner of claim 6 in which the points of intersection of the projected longitudinal axes of the oxygen inlets with the projected longitudinal axes of those fuel inlets which form said corresponding fuel streams are located adjacent said plane transverse to the axis of the chamber.

8. The burner of claim 4 in which the longitudinal position of the burner plate can be adjusted so that the projected longitudinal axes of the oxygen inlets intersect the said cylindrical part.

9. The burner of claim 4 or 8 in which the longitudinal position of the burner plate can be adjusted so that the projected longitudinal axes of the oxygen inlets pass through the open end without intersecting the said cylindrical part.

10. The burner hereinbefore described with reference to or illustrated in the drawings.

11. A method of controlling the pattern of flame discharged from the chamber of an oxygen-fuel burner having a cylindrical combustion chamber of adjustable length with a closed feed end and an open flame discharge end, comprising:—

(1) feeding a plurality of fluent fuel streams from the feed end generally parallel to the longitudinal axis of the chamber towards its open end;

(2) feeding a plurality of oxygen streams from the feed end towards the open end at an angle to the longitudinal axis of the chamber such that each oxygen stream intersects a corresponding said stream of fuel from the feed end; and

(3) adjusting the length of the chamber between its feed and open ends so as to vary the confining effect of the chamber on the pattern of the flame discharged therefrom.

12. The method of claim 11 in which the oxygen streams are fed to the chamber from radially spaced ports in the feed end along paths initially converging on, but not intersecting, the longitudinal axis of the chamber.

13. The method of claim 12 in which a minor portion of the fuel is directed into contact with the oxygen streams at a predetermined axial distance from the feed end in a primary combustion region and a major portion of the fuel is directed in streams outside the oxygen streams so as to intersect them beyond the said primary combustion region in a secondary combustion region.

14. The method of claim 13 in which the oxygen streams are so directed that their respective points of closest approach to the axis of the chamber define a plane transverse to the said axis, the primary combustion region being in and around the said transverse plane and the secondary combustion region being on the side of the plane distant from the feed end.

15. The method of claim 11 substantially as hereinbefore described with reference to the drawings.

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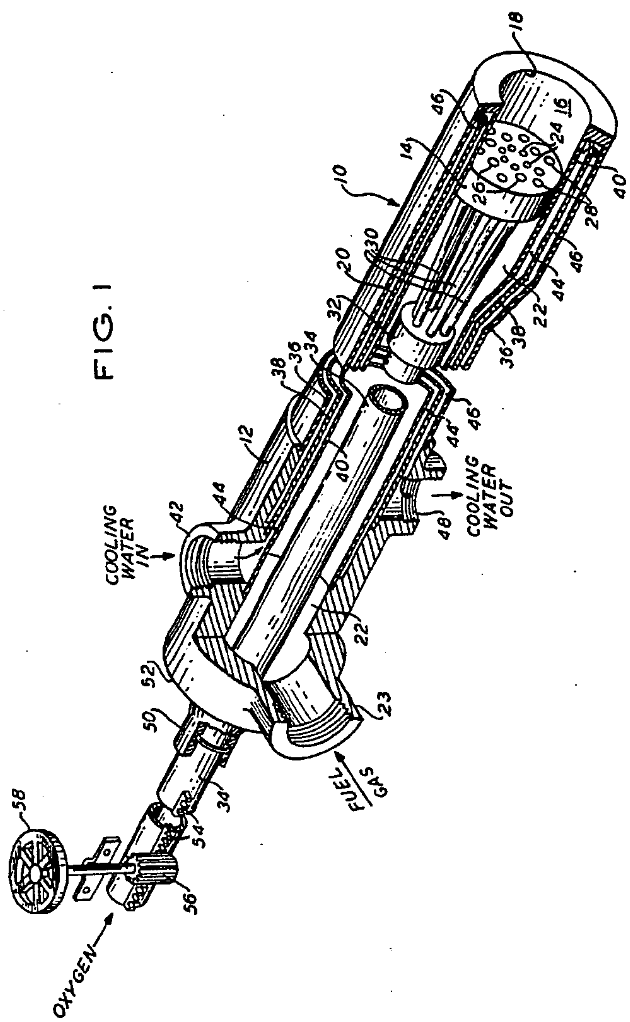
FIG. 1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COOLING WATER IN
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OXYGEN

FIG. 2

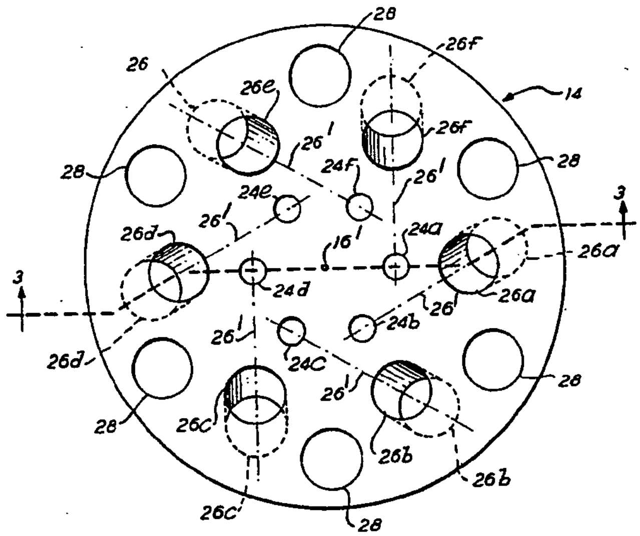
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FIG. 3

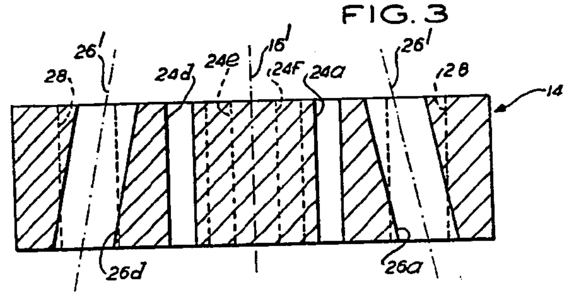
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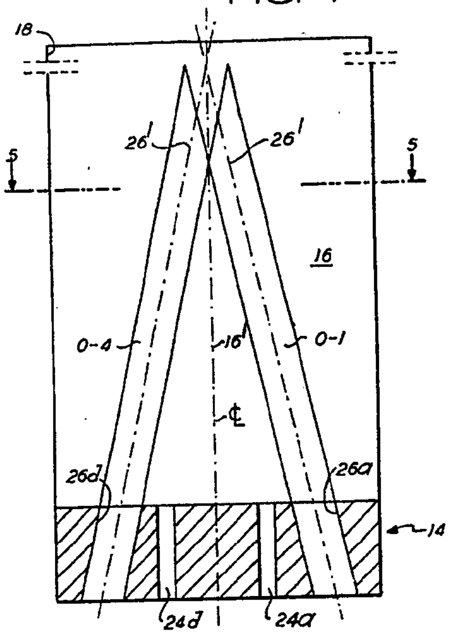
FIG. 4



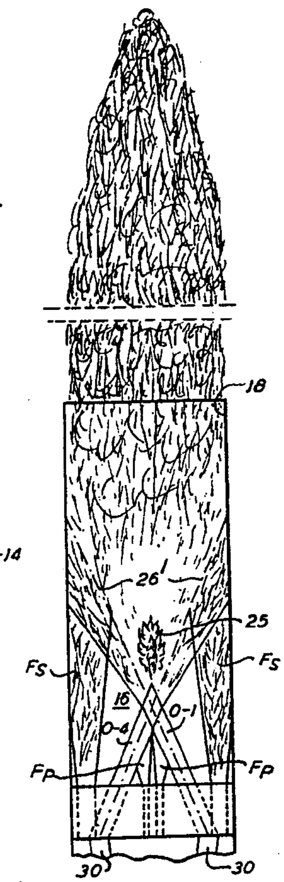
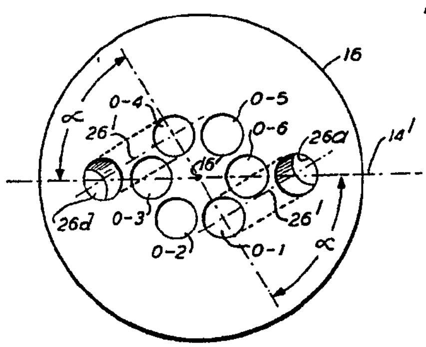


FIG. 7

FIG. 5



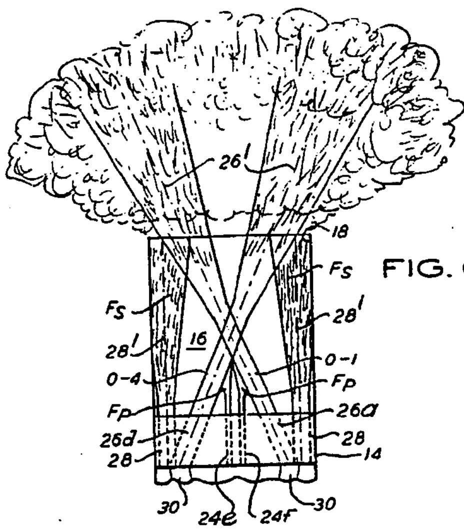

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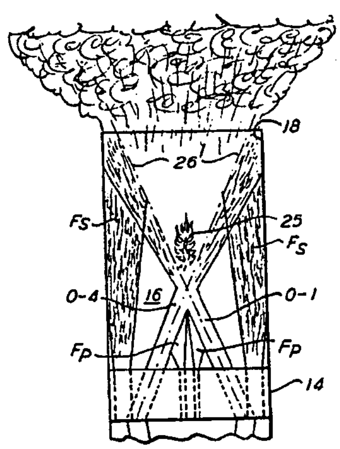
FIG. 6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16
0-1
Fp
Fp
14

FIG. 8